Competitiveness in Vertical Market Chains:

Evidence for Beef Markets

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Robert D. Weaver and William C. Natcher*

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*Professor and Research Assistant,
Department of Agricultural Economics,
Pennsylvania State University
Principal Contact: r2w@psu.edu

Biographical Sketch

Professor Weaver completed a Ph.D. in economics at Wisconsin

Over the past twenty years the U.S. beef industry has experienced significant structural changes and increased market concentration in beef packing. This concentration has led researchers to ask whether market power is being exercised by industry participants. Concentration alone in an industry does not imply noncompetitive behavior, however, it may be a symptom that barriers to entry exist. Alternatively, concentration may have naturally occurred as competitive forces led firms to seek substantial economies of scale or scope. Feather and Sherrick (1992) note vertical integration may reduce the risk of supply uncertainty and increase the efficiency of the firm by reducing cost in the production process. Weaver and Kim (1999) show that where quality or price is uncertain in a supply chain, substantial incentives may exist for vertical integration, even when grades and standards are in place.

Empirical examination of the efficiency and competitiveness of markets has most often involved evidence from estimated models of the conditional mean of prices. The definition of an efficient market states that economic profits will be driven to zero as arbitrage expands to exploit opportunity. This notion implies that all information is instantaneously incorporated in prices by arbitrage and that resulting price changes are independent and identically distributed (iid). This empirical implication has been the traditional basis for time series assessments of the extent of competitiveness in market. Initially, focus was on testing whether the price difference between market prices is i.i.d. or where prices are nonstationary, whether the prices are cointegrated. In either case, the focus remained on the implications of market efficiency for price levels.

This paper will reexamine evidence of market competitiveness and efficiency in U.S. beef markets based on both this traditional approach as well as a significant extension. The paper extends the focus of past studies to include consideration of the transmission of volatility as a means of gauging competitiveness of markets.

In this paper, our attention focuses on the persistence of price levels and volatility and implications for market efficiency across the vertical market chain in U.S. beef. Consideration of both the conditional means and variance jointly affords measurement of both the extent of and the intertemporal persistence of distortions to intertemporal arbitrage equilibrium associated with competitive markets. The paper is part of a stream of ongoing research by the authors that examines the implications for second moments, or price volatility, see e.g. Weaver, et al. (1989) and Loy and Weaver (1998) that consider transmission of prices and its relationship with market structure, or more recently, Weaver and Natcher who considered implications of changing market structure for a variety of commodity markets.

The approach of the paper relies on an integration of recent advances in time series analysis with microeconomic theory of arbitrary applied to pricing behavior. Persistence in levels may be considered using conventional VAR or error correction models. In the application reported here, stationarity of the series allows use of VAR models. Volatility persistence is considered within the framework of a generalized autoregressive conditional heteroskedasticity (GARCH) model (see Engle (1982) and Engle and Bollerslev (1986)). The data used allows consideration of evidence of competitiveness at monthly levels across central and regionally aggregated markets.

To characterize the vertical market chain, observations of prices for retail cuts, wholesale cuts, live cattle and feeder cattle, and feed prices (corn and soybeans) are considered. The frequency of observation allows the results to comment on the efficiency of multiple cattle markets over the sample period. Structural change is necessarily examined first allowing inference to be based on data generated by stable processes.

Transmission of Price Levels and Volatility in Vertical Chains

The issue of vertical transmission of price levels or volatility has had limited attention in the literature. It has received no consideration as evidence of market efficiency except by Loy and Weaver (1998). From the perspective of transmission of price levels, papers have considered vertical price differentials as marketing margins and developed structural theories of their variation. In this paper, we introduce the notion that transmission of prices and their volatility follows from a type of "arbitrage". The good at one market level or stage is arbitraged vertically into another market or stage, not by transportation, or storage, but by transformation. The relationships between price levels or volatility established by this type of vertical arbitrage are only subtly different than those established by other types of arbitrage.

An extensive literature has considered transmission of price level from the perspective of market efficiency. Conventional structural models have been estimated with insertions of measures of firm concentration. This structural approach has been applied using parametric econometrics to the beef market to explicitly determine the impacts of concentration. For example, Schroeder (1988), Azzam and Pagoulatos (1990), and Schroeder and Azzam (1990) find evidence of periodic noncompetitive behavior in the input market for finished cattle. Schroeder (1988) and Schroeder and Azzam (1990) find evidence of market power in the output market for packed beef. Muth (1998) constructed a more general structural model of the beef packing industry to test for market power in both the input and output markets. Her results suggest both the finished cattle and the packed beef markets operate competitively.

Empirical Implications of Efficient Arbitrage

Purely competitive or purely monopolistic markets are polar examples of market structures in which the actions of firms are either inconsequential or completely dominant in determining prices within the market. In the purely monopolistic market, a single seller of a product exists for which there exist no close substitutes and entry into the market is somehow constrained. When such a market condition exists, lack of competition results in the price of the product failing to contain all relevant information about the product. In particular, the adjustment of price will be managed strategically by the dominant firm rather than instantaneously adjusting to demand and supply changes, see Weaver et al. (1989). A similar result occurs when price is determined in a multiple firm game. Although the pure monopoly market provides a foundation on which to study imperfect competition, many market structures display a combination of both competitive and noncompetitive behavior. In this scenario, evidence of exertion of market power to manage commodity prices is difficult to isolate from intertemporal price behavior.

The empirical implications of competitive vs. noncompetitive behavior can be identified through a consideration of arbitrage and determination of prices. To see these different implications, we consider the problem first from the perspective of markets over time, and then, vertically linked markets. Consider first a generalized market clearing condition for a single market linked over time through storage:

1) $$z(p^e_t) + (1-d)S_{t-1} = D(p_t) - v_t + S_t$$

where z_t is the current harvest conditioned by $p^e{}_t$ the price expectation formed at time $t-1$, v_t is a random demand shock, S_t represents current storage at time t, and $D(p_t)$ is demand as a function of current prices. Muth considered the implications of the competitive case when $p^e{}_t$ is a homogeneous, rationale expectation. Helmberger et al. considered the implications of stock-outs, and a stream of literature has generalized the market situation to incorporate futures, options, forward contracts, and other forms of intertemporal arbitrage. Under competitive conditions, prices solve equation 1) and the associated arbitrage conditions. The implications for time series properties of the resulting prices will depend on the functional forms of the arbitrage conditions, the choice functions aggregated into a physical balance condition such as 1) and the exogeneous stochastic processes impacting those choices and conditions.

Where price is not determined by a competitive process, an alternative theory of price determination through dominant firm strategic pricing, or gaming among firms, would lead to a theory of price evolution that differs from the competitive case. In particular, strategic pricing would imply inertia in price adjustment and perhaps asymmetry in adjustment.

A hallmark of an efficient market is free entry into arbitrage that drive arbitrage profits to zero, leaving prices across arbitraged markets linked into a fabric that reflects marginal net benefits of arbitrage. In the simple case of intertemporal arbitrage, suppose arbitrage responds to expectations of profit, and costs are zero, then free entry implies the following "arbitrage equilibrium" condition:

2) $$E[p_{t+1}|\mathbf{W}^c{}_t]=p_t.$$

In the price expectation, $\Omega^c{}_t$ represents all relevant information pertaining to the price p_{t+1}. This arbitrage equilibrium condition provides the basis for conventional tests of market efficiency. For example, by adding a error term to 2), we have the random walk hypothesis examined extensively through either regression tests of zero intercept and unitary slope parameters, or more recently through co-integration.

If prices are determined by noncompetitive processes, this intertemporal arbitrage condition may be distorted in two ways. First, while dominant firms may continue to base decisions on a full information set $\Omega^c{}_t$ that reflects contemporaneous demand and supply conditions, their decisions would also reflect their conjectures concerning the current and possible future behavioral reaction of other firms to that information set. In other words, their decisions would also reflect a subjectively constructed strategic information set $\boldsymbol{W}^s{}_t$. Second, price would be determined by a mechanism that goes beyond the simple the physical balance condition in 1). Here, an infinity of possible games and strategies could be specified, each leading to alternative specifications of a structural approach to the determination of price. In all cases, the level and evolution (dynamics) of equilibrium price could be represented simply by particular functions of the two information sets. Summarizing, under the competitive hypothesis 1) and 2) would imply

$$3) \qquad p_t = p^c(\boldsymbol{W}^c{}_t) \quad dp_t = dp(d\boldsymbol{W}^c{}_t)$$

while a noncompetitive hypothesis would imply an alternative to 3):

$$4) \qquad p_t = p^c(\boldsymbol{W}^c{}_t, \boldsymbol{W}^s{}_t) \quad dp_t = dp(d\boldsymbol{W}^c{}_t, d\boldsymbol{W}^s{}_t).$$

While the above notation excludes vertical linkages, its implications are clear for such markets if we simply replace dp_t in 3) with the difference between prices at two levels of processing. That is, we need only think of vertical transformation as a type of arbitrage where the product form is transformed physically, rather than simply by storage or transportation, to access greater returns in vertically linked market. In this case, we can generate much the same story as above.

Suppose that for the i^{th} upstream market, arbitrage involves profit maximizing transformation of downstream supply $S_{i-1.}$ The arbitrage equilibrium condition would follow from free entry driving these profits to zero. That is, defining profits

$$5) \qquad \mathbf{p}_{it} = p_{it}\, Y_{i,i-1} - p_{i-1t}\, Y_{i,i-1} - C(Y_{i,i-1})$$

While the competitive agent would maximize 5) given prices, a noncompetitive agent would choose quantity along some portion, or all, of the demand curve. In the competitive case, free entry would drive profits to zero, implying an arbitrage equilibrium condition as follows:

$$6) \qquad p_{it} - p_{i-1t} - AC(Y_{i,i-1}) = 0$$

Physical balance equilibrium in this simple model would then be:

$$7) \qquad Y_i\,(p_i\,, Y_{i-1}(p_{i-1}\,)) = D(p_i\,)$$

From this specification, it is clear that equilibrium prices along the vertical chain would be linked by arbitrage, reflecting only the transformation and marketing margin, here $AC(Y_{i,i-1})$.

Empirical Implications of Noncompetitive Behavior

While the above theories motivated consideration of evidence of efficient arbitrage at the market level, an alternative would be to directly examine evidence of noncompetitive behavior. In the noncompetitive case, maximization of profits would follow from choice of quantity along some portion of the demand curve. This would imply the margin revenue associated with the first-order condition would not be constant, but reflect market power as a function of volume.

This approach has a long history of application. Various parameterizations of such first-order conditions have been articulated to allow identification of marginal revenue that might vary with quantity or indicators of concentration, see Applebaum (1982), Bresnahan (1982), and Lau (1982). These parameterizations could be complicated by extension into dynamic behavioral hypotheses see e.g. Steen and Salvanes, among others. However, both the logic and power of this approach is brought to question by the simple fact that it nests the competitive specification within a specific articulation of a noncompetitive alternative hypothesis, leaving inference conditioned by the particular noncompetitive specification adopted.

Lau and Yotopoulos (1974) parametrically estimated the distance between price and marginal cost opening up the notion that parametrically (e.g. Atkinson and Halvorsen, 1980) or nonparametrically (e.g. Love and Shumway, 1994) allocative efficiency could be examined. However, once again, both parametric and nonparametric results may be questioned given the specification uncertainty from which they emerged. Nonparametric results are especially sensitive to specification error in functional properties, inclusion of variables, as well as in dimension of the model (number of variables), and sample.

Arbitrage Equilibrium Examined by Time Series Approaches

As an alternative to structural, parametric or nonparametric approaches that parameterize specific hypotheses of microeconomic behavior, we next reconsider the less restrictive approach of focusing on the arbitrage equilibrium condition. Researchers have employed various time series techniques to study competitiveness in markets based on this condition. Weaver et al. (1989) considered the impact of local market structure on the speed of transmission of price change within retail grocery markets. Loy and Weaver (1998) considered transmission of volatility in food prices across space in Russia. Recent literature considering livestock includes Khan and Helmers (1997) who investigated the relationship between the input price of corn and livestock prices over three regimes within a VAR framework. They hypothesize that the increased volatility in corn prices led to the structural changes in the livestock industry and they conclude that beef is more susceptible to changes in corn price than is pork. Schroeder (1996) used a VAR model to investigate spatial price integration among 28 beef packing plants. Results suggest that daily prices are generally cointegrated but distance between plants weakens the spatial price linkages. Moreover, plants that purchased a large percentage of cattle through noncash instruments tended to have weaker long-run relationships suggesting that non-geographic factors impact price relationships.

To consider the potential of this approach, relax the requirement of strict arbitrage equilibrium. Supposing it holds only in expectation, conditionally on available information, we have:

$$8)\qquad P_{it} = P_{i-1t} + AC(Y_{i,i-1}) + e_{i,i-1,t}$$

Supposing that the information set available to each market stage is the same, we have the result that $E_t(\varepsilon_{i,i-1,t} \mid P_{i-1,t}) = 0$. The results here are equivalent to conventional implications of efficient markets hypotheses. Where the prices are stationary, the hypothesis of efficient arbitrage could be examined by regression, though the conditional mean condition would best be enforced using GMM to ensure results do not reflect simultaneity bias. Where the price levels are nonstationary, long-term co-movement in levels may be considered through an examination of co-integration. Differencing the arbitrage equilibrium condition results in a form that could be useful if the prices are I(1), i.e.

9) $dP_{it} - dP_{i-1t} - dAC(Y_{i,i-1}) = 0$

or adding a stochastic term,

10) $dP_{it} = dP_{i-1t} + dAC(Y_{i,i-1}) + \varepsilon_{i,i-1,t}$.

What are the implications of efficient arbitrage for the relationships across markets or stages of price volatility? This can be derived from a theory of arbitrage under risk aversion, see Weaver (1999).

The empirical implications of vertical arbitrage for prices and volatility can be explored directly using the GARCH model. Define $R_{it} = dp_{it}$, then the arbitrage equilibrium condition can be viewed as a restriction of the following relationship:

11) $$R_{it} = \beta + \sum_{j=1}^{p} \phi_j R_{it-j} + \sum_{j=1}^{p} \theta_j R_{i-1t-j} + \varepsilon_{it} \qquad \varepsilon_{it} \sim N(0, h_{it}) \qquad \forall i$$

Here, R_{it} is the change in the price of commodity i in month t. The right hand side of this expression includes autoregressive processes in own stage and "previous stage" price differences. Given a vector of prices through a supply chain, it is clear that these relationships would define a vector autoregressive model, VAR.

The conditional variance of the error in this type of model of price often reflects heteroskedasticity that can be parsimoniously represented by some form of GARCH(p,q) process (see Engle (1982), and Engle and Bollerslev (1986)), e.g.

12) $$h_{it} = \boldsymbol{a}_i + \boldsymbol{g}_i S_{it-1} + \sum_{j=1}^{q} \boldsymbol{r}_{ij} \boldsymbol{e}^2{}_{it-j} + \sum_{j=1}^{p} \boldsymbol{r}_{ij} h^2{}_{it-j} + \boldsymbol{m}_{it} \qquad \boldsymbol{m}_{it} \sim i.i.d\,(0,1)$$

where S_{it} is a vector of current stock levels and other structural determinants of the a time varying conditional variance. As in the case of the relationships across price differences defined above, it is likely that the conditional variances across different market stages are interdependent. As written, the GARCH(p,q) is univariate. To investigate the possibility of interdependence in volatility, we estimate a VAR in estimated conditional volatilities.

Empirical Evidence of Market Efficiency in the Beef Supply Chain

We next explore time series evidence of efficient arbitrage by considering of prices and volatility in beef markets based on data for monthly cash prices ranging from farm level to retail level for recent periods of time, see Table 1. For livestock input prices we focus on corn and soybeans, for output prices live and feeder cattle, for processed products we examine wholesale and retail prices. Use of monthly data allows consideration of the market chain through the retail level. Previous research considered daily data and found no evidence of market inefficiency, see Weaver and Natcher (1999).

Graphic evidence of price variation over time

Graphics for the prices analyzed are presented in Figure 1. While prices at all market levels vary over time, there is no apparent co-movement in levels. Farm level prices appear to have varied more than prices further upstream. This is notable for cattle and beef prices. In general, none of these price series reflect strong trends, though wholesale and retail beef prices seem to follow a series of three or so year trends. The farm level grain prices show dramatic spikes, while the upstream price spikes are smaller in percentage. Cattle prices show a substantial adjustment in late 1986 that persists through 1994. Following a downward spike, they revert to the range of 90 cents/lb. Grains show spikes, particularly in 1996, though prices revert.

Nonstationarity of price levels

Augmented Dickey-Fuller (1979) (ADF) tests indicate each price series is non-stationary, though I(1). A constant term and trend term were included in the estimated ADF equations. Further, the optimal lag length was determined by minimizing the AIC criteria. First differences of each series were found to be stationary, I(0). Results are available from the authors.

Nonstationary price levels are not co-integrated

The results from the ADF tests motivated the use of co-integration tests to determine if a long-run relationship exists between pairs of prices. For example, to examine the relationship between live and feeder cattle prices and between each of these and the feed input prices, Johansen (1988, 1991) co-integration tests were conducted on price levels for these four commodities. The results are available from the authors. No co-integration was found between pairs of these price level variables. This suggests that, in the long-run, the prices move according to their own fundamentals.

These results are consistent with the interpretation that price adjustment is instantaneous, shocks to feed prices are transmitted rapidly into cattle prices, leaving no long-term relationship. In other words, if corn and live cattle prices were co-integrated, then this would imply information in either market could be used to forecast prices in the other markets. This would imply persistence in the transmission of the shock from one product market to the other, contradicting the notion that markets are efficient and arbitrage between markets is efficient. The lack of evidence supporting co-integration between live cattle and feeder cattle price differences similarly supports market efficiency. As previously mentioned, although these commodities share common fundamentals, their adjustment to those fundamentals appears to rapid, leaving their relationship a contemporaneous short-term one, rather than a long-term one.

Multivariate structure of change in price series: VAR evidence

The relationships among price differences in the beef supply chain are considered next. Recalling the price differences are interpretable as “surprises” or “shocks”, unanticipated based on past fundamentals, the price differences provide an important perspective on how such “news” is transmitted through the supply chain. First, the interrelationship across first differences of the price series are investigated based on a vector autoregressive (VAR) model. The Sims (1980) modified likelihood ratio test was used to determine the optimal lag length and was found to be seven lags. AIC and SIC criteria generated similar results. VAR results presented in Table 2 suggest the structure of the interrelationships among these series.

Significant autocorrelation is found for corn, feeder cattle and live cattle prices in the beef chain, though not for wholesale and retail prices. Evidence of interrelatedness between corn and soybean prices confirm their joint determination in the feed complex. However, a significant role of wholesale and retail beef prices as determinants of corn prices suggests vertical feedback within the beef supply chain. As wholesale prices increase corn prices increase; as retail prices increase, corn prices decrease. Results suggest some feedback from wholesale and retail levels to feeder prices, though the relationships are weak. Live cattle prices are found to respond negatively to retail price increases. Wholesale prices respond positively to live cattle prices and negatively to retail prices, as would be predicted by theories of competitive prices in market chains.

Together these results provide reasonable evidence that transmission of price levels in the beef supply chain are consistent with the predictions of competitive price theory. Unanticipated shocks appear to be rapidly absorbed, no strong evidence of inertia in adjustment was found. Only limited feedback through the supply chain was found.

Evidence of transmission of price volatility through the beef supply chain

We next turn to consider price volatility as estimated by conditional variance based on GARCH models discussed above. GARCH models were estimated for each series of price differences based on specifications that optimized their fit according to the SIC. This approach involves simultaneously choosing lag lengths for both the elements of the conditional mean and conditional variance. Results are available from the authors. Figure 2 presents estimated conditional variances for the beef market prices.

Based on these estimates, we next examine evidence of transmission of price volatility through the vertically linked markets in the beef supply chain. We focus on VAR estimates of interrelatedness of those estimated conditional variances across prices in the beef supply chain. Based on estimated GARCH models, estimated conditional variances were generated for each commodity price series except feeder cattle. GARCH results for this product were found to support a fixed variance over time. A VAR model for the conditional variances was estimated where the optimal lag was determined using the Sims modified likelihood ratio test starting with an initial lag length of 35.

The results from the VAR model of conditional variances are presented in Table 3. The results strongly support the conclusion that only weak relationships exist among the conditional variances with the most significant being the own conditional variance lag. Further, transmission appears to be nearly instantaneous. Lag length is very short, indicating adjustment is rapid to changing market conditions. Corn price volatility adjusts rapidly and is found independent of price volatility in other products in the supply chain. Consistent with results based on price differences, results indicate that soybean price volatility is affected by last month's corn price volatility. Further, feedback is again found from wholesale beef price volatility to soybeans. Live cattle price volatility is found independent of other product price volatility though responsive to its own last month's volatility. This suggests some slowness in adjustment to price shocks. Similar results are found for wholesale beef.

Conclusions

Two approaches to examining evidence of market efficiency are presented. At the market level, efficient markets imply arbitrage drives out profits linking prices across markets. It follows that when markets are efficient, changes in price and volatility in prices is transmitted rapidly across markets. An alternative approach is to examine specific hypothesis concerning noncompetitive behavior based on its implications for first-order conditions for agent choices. In this paper, we focus on the arbitrage equilibrium implications of efficient markets and examine efficiency in the beef supply chain based on monthly prices.

Consistent conclusions are found for the transmission of prices and their volatility across the supply chain. In both cases, we find that shocks occurring at one point in the supply chain are rapidly transmitted to other points in the supply chain. Evidence suggests strongly that such transmission is instantaneous as one would expect in a competitive market chain. That is, although a shock might initially affect on point on the supply chain, it is instantaneously transmitted such that one could conclude the supply chain is affected by common shocks. Importantly, no evidence of strategic inertia in transmission is found. Such evidence would suggest that market power is exerted along the supply chain to inhibit rapid adjustment to shocks.

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Figure 1. Monthly Prices in the Beef Supply Chain

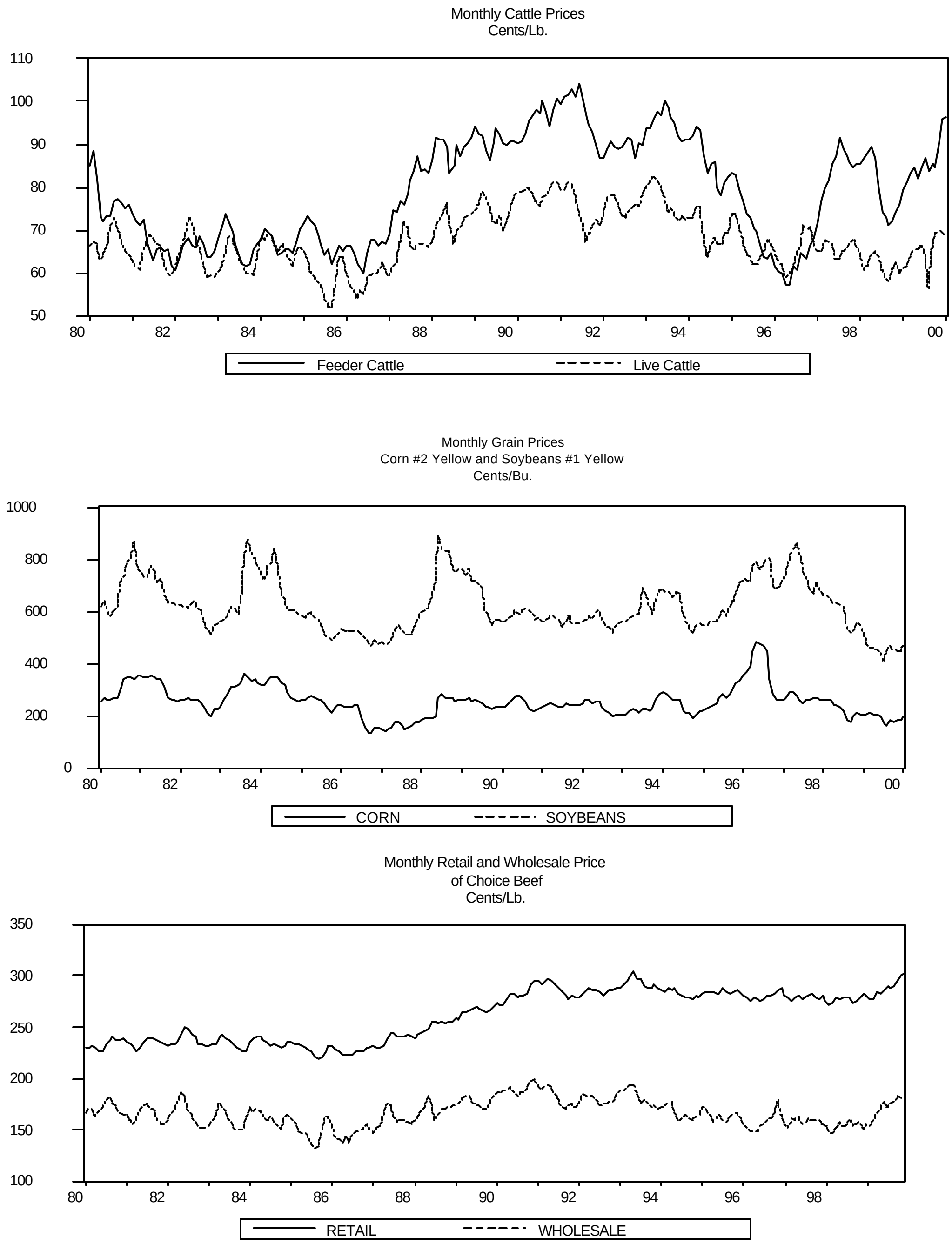


Table 1. Data Series and Descriptive Statistics: Monthly Price Levels

Monthly Data Description

Commodity	Description	Units
Corn	#2 Yellow, Chicago	Cents/bu.
Soybeans	#1 Yellow, Central Illinois	Cents/bu.
Feeder Cattle	Oklahoma City Cash Price	Cents/lb.
Live Cattle	Texas/Oklahoma Cash Price	Cents/lb.
Wholesale Beef	Average Geographic Price of Choice Beef (USDA)	Cents/lb.
Retail Beef	Average Geographic Price of Choice Beef (USDA)	Cents/lb.

Descriptive Statistics of Monthly Price Differences

	CORN	SOYBEANS	FEEDER	LIVE	WHOLESALE	RETAIL
Mean	0.160660	0.537404	0.177660	0.111671	0.294986	0.566295
Median	0.387000	0.738000	0.210000	0.040000	0.100000	0.200000
Maximum	69.73100	247.0140	8.520000	9.560000	16.80000	14.60000
Minimum	-108.7100	-252.9540	-8.850000	-8.600000	-15.00000	-11.20000
Std. Dev.	15.99396	45.97467	2.610387	2.520910	5.698209	3.609679
Skewness	-0.699690	0.108375	-0.211854	0.186580	0.219643	0.469497
Kurtosis	10.27398	11.89081	3.707688	3.981492	3.213719	3.839483
Jarque-Bera	820.7488	1183.106	10.17690	16.49267	3.569767	23.73053
Probability	0.000000	0.000000	0.006168	0.000262	0.167817	0.000007
1/1980-1/2000 Observations	359	359	359	359	359	359

Table 2. VAR Results for Price Differences in Beef and Dairy Supply Chains
Beef Complex Vector Autoregression Based on Price Differences (1980-1999)

Included observations: 240
Standard errors & t-statistics in parentheses (Critical Value=1.65 at a test size of .05)

	SOYBEANS	**CORN**	**FEEDER**	**LIVE**	**WHOLESALE**	**RETAIL**
SOYBEANS(-1)	0.108181	-0.036443	0.003235	-0.000617	-0.008056	-0.000454
	(0.07659)	(0.03357)	(0.00562)	(0.00523)	(0.01141)	(0.00529)
	(1.41256)	(-1.08562)	(0.57527)	(-0.11805)	(-0.70632)	(-0.08594)
CORN(-1)	0.412692	0.505333	0.002938	0.008736	-0.019408	0.006329
	(0.15962)	(0.06996)	(0.01172)	(0.01090)	(0.02377)	(0.01102)
	(2.58551)	(7.22287)	(0.25064)	(0.80135)	(-0.81648)	(0.57437)
FEEDER(-1)	0.723317	-0.353183	0.286612	0.051702	0.020930	0.054048
	(0.92673)	(0.40620)	(0.06805)	(0.06329)	(0.13801)	(0.06397)
	(0.78050)	(-0.86948)	(4.21205)	(0.81687)	(0.15165)	(0.84484)
LIVE(-1)	0.252220	-0.630735	-0.008953	0.212707	0.874506	0.300122
	(1.52432)	(0.66814)	(0.11192)	(0.10411)	(0.22700)	(0.10523)
	(0.16546)	(-0.94402)	(-0.08000)	(2.04317)	(3.85242)	(2.85213)
WHOLESALE(-1)	0.358761	0.611833	-0.052263	0.070142	0.022018	0.247815
	(0.67632)	(0.29644)	(0.04966)	(0.04619)	(0.10072)	(0.04669)
	(0.53046)	(2.06391)	(-1.05243)	(1.51855)	(0.21861)	(5.30789)
RETAIL(-1)	-1.116025	-0.696265	0.096572	-0.196193	-0.395771	0.031299
	(0.76664)	(0.33603)	(0.05629)	(0.05236)	(0.11417)	(0.05292)
	(-1.45574)	(-2.07204)	(1.71559)	(-3.74709)	(-3.46659)	(0.59141)
R-squared	0.076586	0.233510	0.090394	0.133972	0.178389	0.443703
Adj. R-squared	0.056855	0.217132	0.070958	0.115467	0.160833	0.431817
Sum sq. resids	260909.8	50126.29	1406.651	1216.996	5786.220	1243.353
F-statistic	3.881515	14.25755	4.650858	7.239832	10.16126	37.32776
Log likelihood	-1179.500	-981.5447	-552.7446	-535.3655	-722.4567	-537.9366
Akaike AIC	9.879168	8.229539	4.656205	4.511379	6.070473	4.532805
Schwarz SC	9.966184	8.316555	4.743221	4.598395	6.157489	4.619821
Mean dependent	-0.803596	-0.355908	0.047583	0.006750	0.043333	0.305000
S.D. dependent	34.38334	16.54172	2.543710	2.424821	5.428319	3.058053
Log Likelihood		-4319.655				
Akaike Information Criteria		36.29712				
Schwarz Criteria		36.81922				

[c]Optimal lag chosen by minimizing the SIC

Table 3. Summary of VAR results for Conditional Variances

Beef Complex Vector Autoregression Based on Conditional Variance Estimates (1980-1999)[c]*

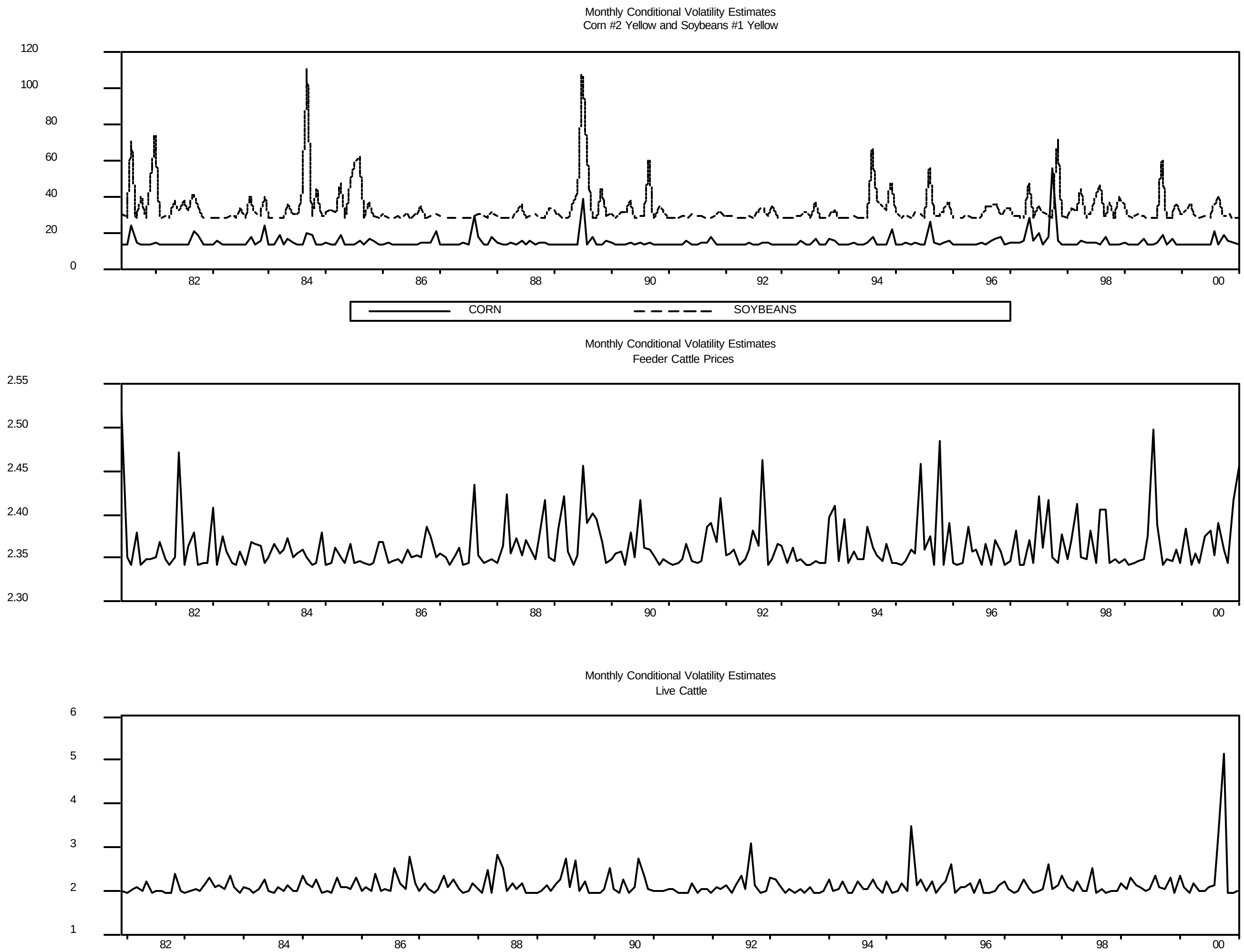
Included observations: 229
Standard errors & t-statistics in parentheses (Critical Value=1.65 at a test size of .05)

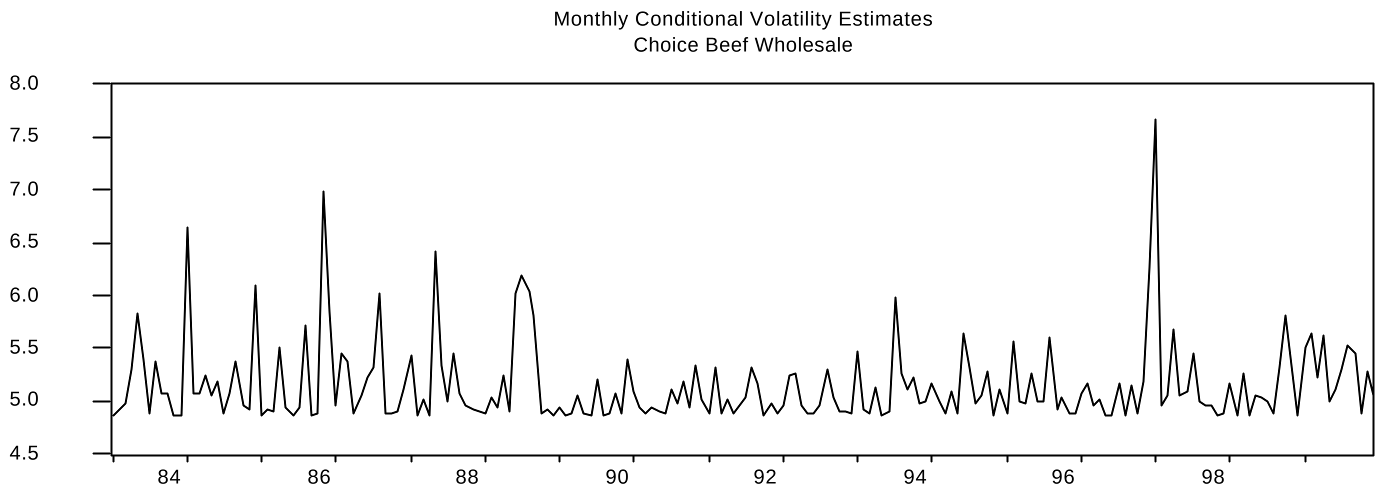
	SOYBEANS	**CORN**	**FEEDER**	**LIVE**	**WHOLESALE**
SOYBEANS(-1)	0.110571	0.003410	4.85E-05	0.002214	0.004149
	(0.06891)	(0.02663)	(0.00018)	(0.00199)	(0.00260)
	(1.60460)	(0.12806)	(0.26501)	(1.11534)	(1.59474)
CORN(-1)	0.439012	0.020205	-0.000423	-0.006542	0.000670
	(0.18540)	(0.07165)	(0.00049)	(0.00534)	(0.00700)
	(2.36786)	(0.28199)	(-0.85799)	(-1.22478)	(0.09564)
FEEDER(-1)	-3.596869	13.95471	0.018932	0.445644	-0.268707
	(25.9953)	(10.0459)	(0.06909)	(0.74885)	(0.98147)
	(-0.13837)	(1.38909)	(0.27404)	(0.59510)	(-0.27378)
LIVE(-1)	-2.324843	-0.155526	-0.004840	0.126791	-0.046942
	(2.22777)	(0.86093)	(0.00592)	(0.06418)	(0.08411)
	(-1.04358)	(-0.18065)	(-0.81749)	(1.97569)	(-0.55809)
WHOLESALE(-1)	3.514526	0.992187	0.003144	0.009646	0.144179
	(1.84064)	(0.71132)	(0.00489)	(0.05302)	(0.06949)
	(1.90941)	(1.39486)	(0.64281)	(0.18192)	(2.07467)
INTERCEPT	18.29614	-23.19677	2.316625	0.775257	4.998518
	(60.5314)	(23.3925)	(0.16087)	(1.74374)	(2.28541)
	(0.30226)	(-0.99163)	(14.4005)	(0.44459)	(2.18714)
R-squared	0.068113	0.021154	0.008050	0.030309	0.033885
Adj. R-squared	0.047219	-0.000793	-0.014191	0.008568	0.012224
Sum sq. resids	23212.89	3466.735	0.163954	19.26328	33.09004
F-statistic	3.259896	0.963876	0.361964	1.394055	1.564296
Log likelihood	-853.7828	-636.0616	504.2598	-41.48974	-103.4378
Akaike AIC	7.509020	5.607525	-4.351614	0.414758	0.955789
Schwarz SC	7.598986	5.697492	-4.261648	0.504724	1.045756
Mean dependent	33.25124	14.97082	2.362622	2.121367	5.155824
S.D. dependent	10.45239	3.941267	0.026925	0.295176	0.387585
Log Likelihood		-1094.870			
Akaike Information Criteria		9.824192			
Schwarz Criteria		10.27402			

[c]Optimal lag chosen by minimizing the SIC

*Monthly retail prices were found to have a constant variance and consequently were not included in the VAR model.

Figure 2. Conditional Volatility Estimates of Price Volatility




Monthly Conditional Volatility Estimates
Choice Beef Wholesale
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
84
86
88
90
92
94
96
98